

Deficit Irrigation and Split Nitrogen Fertilization under Conservation Tillage: Effects on Winter Rapeseed Yield and Biodiesel Quality

Lucian Dordai, Anca Becze, Marius Roman

INCDO-INOE2000, Research Institute for Analytical Instrumentation, ICIA Cluj-Napoca Subsidiary, 400293 Cluj-Napoca, Romania
lucian.dordai@icia.ro

INTRODUCTION

Conservation agriculture and minimal-tillage systems are gaining momentum for reducing the environmental footprint and improving the sustainability of agricultural production. Combining cover crops with minimal tillage offers multiple benefits: reduced soil erosion, higher organic matter content, improved soil structure, and lower production costs.

Winter rapeseed (*Brassica napus* L.) remains the European Union's leading biodiesel feedstock, but growing water scarcity and rising fertilizer costs call for optimized irrigation and nitrogen-management strategies that safeguard both seed yield and fuel quality.

Main objective

To evaluate how irrigation regime and split nitrogen fertilization, combined with conservation tillage, affect winter rapeseed seed yield, oil content, and the physicochemical/emission properties of the resulting biodiesel.

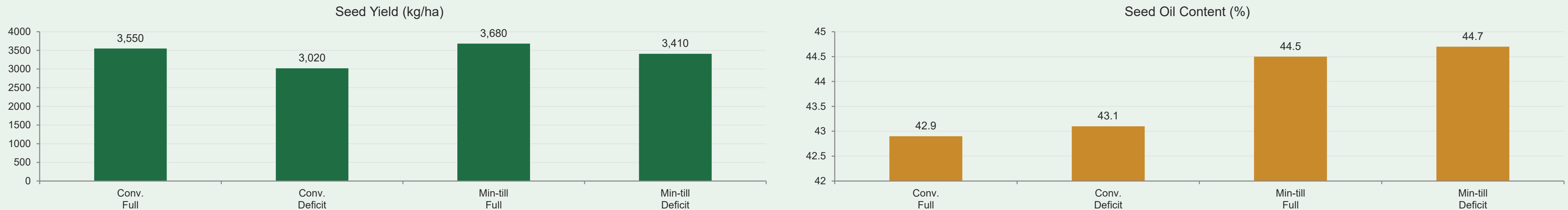
Hypotheses

- Deficit irrigation with split N maintains yield within 10% of full irrigation while improving water-use efficiency.
- Conservation tillage with cover crops buffers yield loss under reduced irrigation.
- Biodiesel from all treatments meets EN 14214 limits, with lower-input treatments reducing exhaust emissions.

METHODOLOGY

- Study design** 3-year field trial (2023–2025) near Cluj-Napoca (Transylvanian Plain); split-plot randomized block design, 4 replicates; 2 tillage systems × 2 irrigation regimes × N-splitting.
- Irrigation schedule** Autumn 300 m³/ha, Spring 400 m³/ha, Summer 500 m³/ha (drip); deficit regime at 70% of scheduled volumes.
- Nitrogen application** 25% autumn, 60% spring, 15% after flowering (total 160 kg N/ha).
- Tillage & cover crops** Conventional tillage vs. minimal (strip-) tillage with a mixed cover crop preceding rapeseed sowing.
- Biodiesel production** Methanol transesterification, KOH catalyst, 6:1 methanol:oil ratio.
- Quality analysis** Cetane number, sulfur content, calorific value (EN 14214); emissions: CO, HC, PM₁₀, NO_x (engine bench tests).
- Statistics** ANOVA and multiple regression (R 4.3.2).

RESULTS & DISCUSSION



Key findings: Minimal tillage with cover crops buffered the yield penalty of deficit irrigation, narrowing the yield gap from 15% (conventional) to 7.3% (conservation system) relative to full irrigation ($p < 0.01$). Oil content averaged 43.8% and was not significantly affected by irrigation regime ($p = 0.21$) but rose by 1.6 percentage points under split N fertilization. Water-use efficiency improved by 22% under deficit irrigation combined with conservation tillage. Biodiesel from all treatments met EN 14214 limits: cetane number 52.4–54.1, sulfur content < 8 mg/kg, calorific value 39.6–40.3 MJ/kg.

Implications: Conservation tillage reduced diesel fuel use for field operations by ~31 L/ha/year and lowered production costs by 9–12%. Engine bench tests showed 11% lower PM₁₀ and 8% lower NO_x emissions for biodiesel from deficit-irrigated, conservation-tillage plots compared with conventional full-irrigation biodiesel, consistent with a more favorable fatty-acid profile (higher oleic, lower linolenic acid).

CONCLUSIONS

- Combining minimal tillage with cover crops and split nitrogen fertilization offsets most of the yield loss caused by deficit irrigation in winter rapeseed.
- Seed oil content and biodiesel quality remained within EN 14214 standards across all management scenarios.
- Deficit irrigation under conservation tillage improved water-use efficiency by 22% without compromising fuel quality.
- Biodiesel emission profiles were sensitive to agronomic management, favoring lower-input, conservation-based systems.
- These results support integrating conservation agriculture practices into biodiesel-feedstock production to improve both resource-use efficiency and fuel sustainability.

Policy recommendations: Promote conservation tillage and cover-crop adoption in energy-crop rotations, support deficit-irrigation scheduling tools for farmers, and align biodiesel-feedstock subsidies with verified soil- and water-conservation outcomes.

REFERENCES

- LOVASZ, Andra, et al. Production and quality of biodiesel under the influence of a rapeseed fertilization system. *Energies*, 2023, 16.9: 3728.
- WENZHONG, Huang, et al. Optimizing Rapeseed Oil Yield for Sustainable Biodiesel Production. *Journal of Energy Bioscience*, 2024, 15.

ACKNOWLEDGMENT

This work was supported by a grant of the Ministry of Education and Research, CCCDI—UEFISCDI, project number PN-IV-P6-6.1-CoEx-2024-0025, within PNCDI IV. This work was carried out through the Core Program within the National Research Development and Innovation Plan 2022–2027, with the support of MCID, project no. PN 23 05.